ECE343 Spring 2025

Objective 9.4:
UPW Polarization



UNITED STATES
AIR FORCE
ACADEMY

SCHEDULE

Lesson	Topics	Reading	Notes
24	BVP (Capacitor, Coax), Electric Potential	5.16	LO 5.3
25	Electric Boundary Conditions	5.18-5.22	LO 5.4
26	BC's/Capacitance	5.23-5.24	
27	Electrostatic Lab	Lab packet	
Chapter 6: Steady Current & Conductivity			
28	Current density, Conductivity, Resistance	Ch. 6	
Chapter 7: Magnetostatics			
29	Magnetic Fields, Gauss' Law for Magnetism	7.1-7.3	LO 7.1-7.2 **GR 2**
30	Ampere's Law	7.4-7.5, 7.9	LO 7.3
31	Ampere's Law Applied	7.6-7.8	LO 7.3
32	Magnetic Boundary Conditions	7.10-7.14	LO 7.4
33	Magnetostatics Lab	Lab packet	
Chapter 8: Time-Varying Fields			
34	Faraday's Law, Displacement Current, Maxwell Eqns	8.3, 8.8, 8.9	LO 8.1
35	Faraday's Law, Displacement Current, Maxwell Eqns	8.3, 8.8, 8.9	LO 8.2-8.3
Chapter 9: Plane Waves in Lossless Media			
36	Maxwell's Equations in lossless, source-free region	9.1-9.2	LO 9.1
37	Maxwell's Equations in lossless, source-free region	9.1-9.2	LO 9.1
38	Uniform Plane Waves & Polarization	9.4-9.6	LO 9.2-9.3
39	Normal Incidence	Vol 2, 5.6-5.7	LO 9.4-9.5
40	Oblique Incidence	Vol 2, 5.6-5.7	LO 9.5
41	Oblique Incidence	Vol 2, 5.6-5.7	LO 9.5
42	Incidence Lab	TBD	LO 9.5

Ch 9 Learning Objectives

9.1 I understand the process of decoupling and finding solutions for Maxwell's equations for dynamic fields.

9.2 I can articulate what a Uniform Plane Wave (UPW) is and describe key properties that relate the electric and magnetic field.

9.3 I can calculate the electric and magnetic fields for a UPW.

9.4 I can articulate the concept of polarization and determine the polarization for various UPWs.

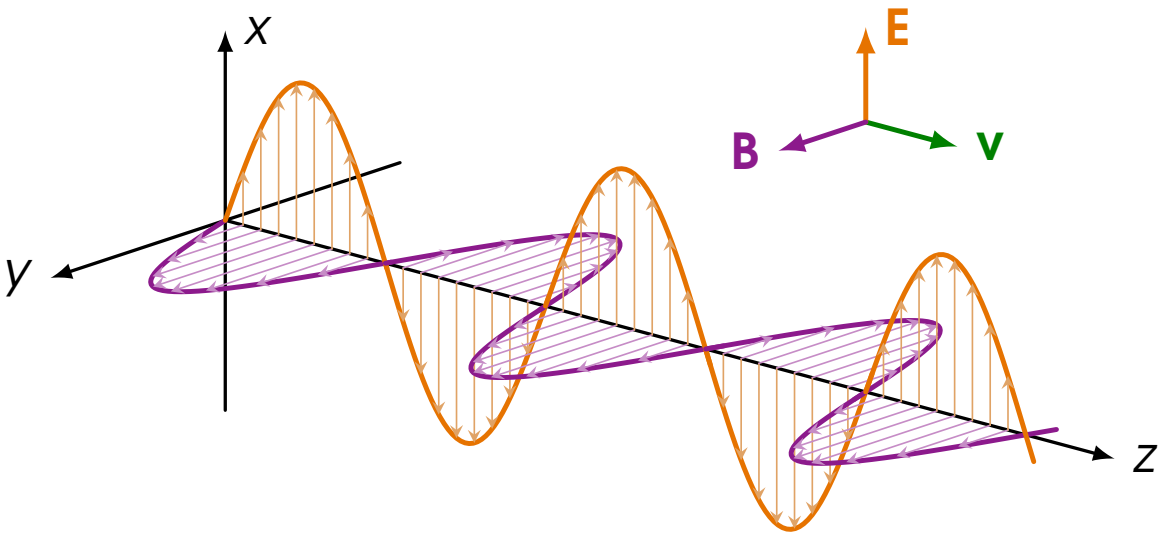
9.5 I can determine the reflection and transmission of UPW at a boundary for Transverse Electric (TE) and Transverse Magnetic (TM) waves, using boundary conditions.

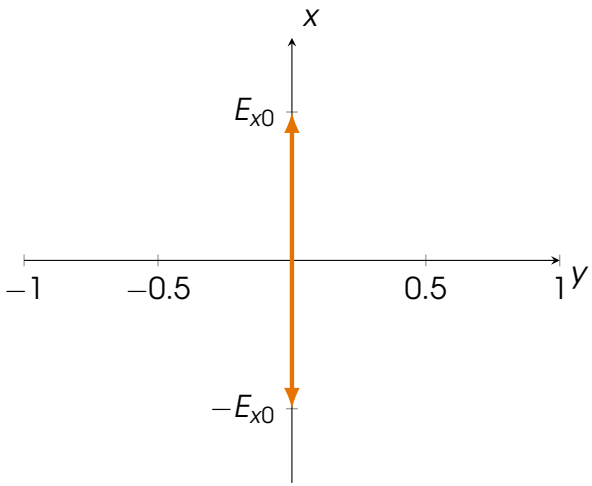
Uniform Plane Waves: Polarization

Definition

Polarization is the orientation of the electric field vector.

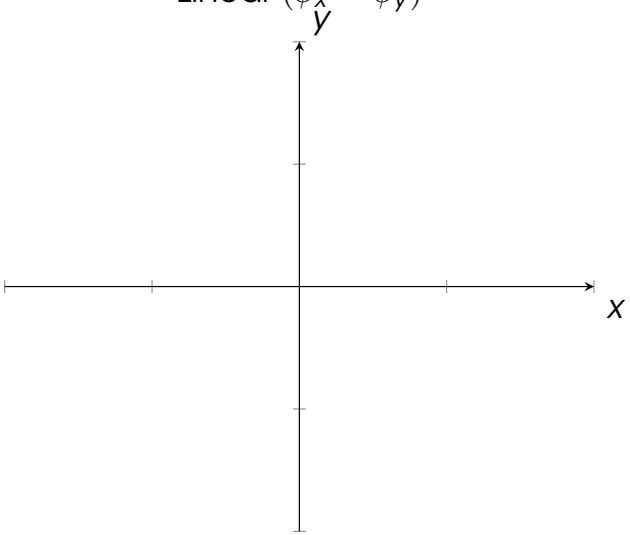
Time-harmonic behavior affects polarization.



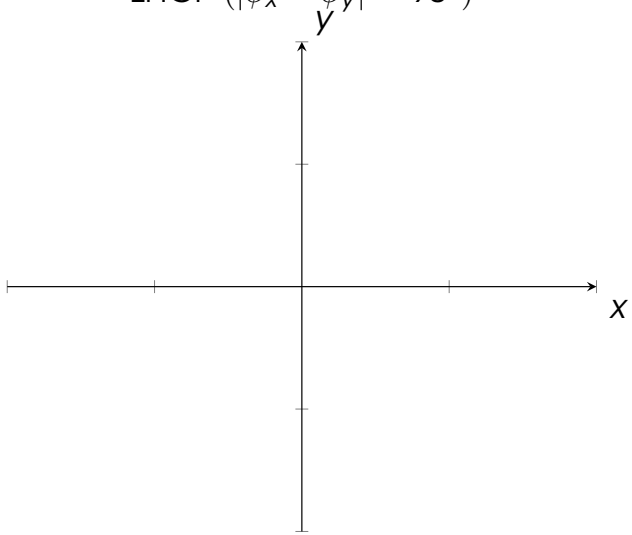


Types of Polarization

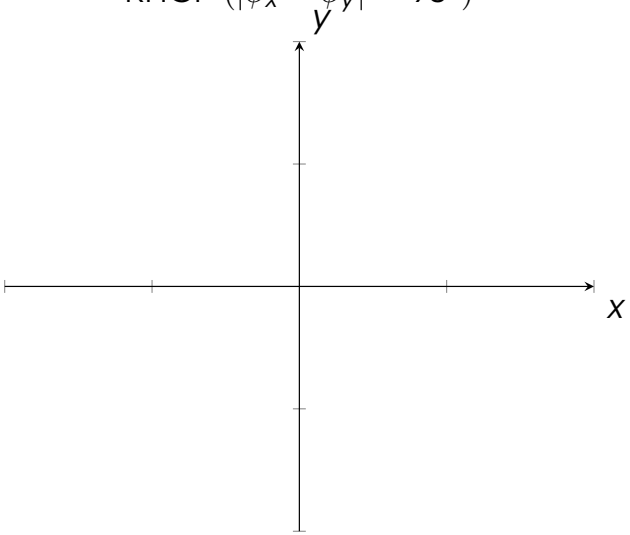
Linear ($\phi_x = \phi_y$)



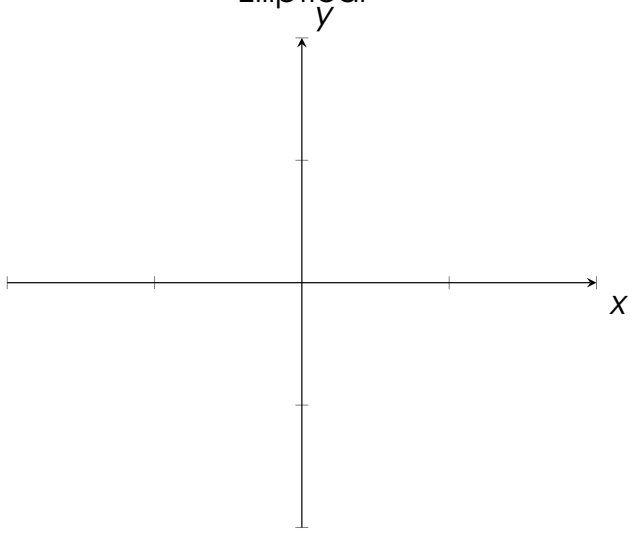
LHCP ($|\phi_x - \phi_y| = 90°$)



RHCP ($|\phi_x - \phi_y| = 90°$)



Elliptical



Uniform Plane Waves: Polarization # 1

$$\vec{E}(z,t) = \hat{\mathbf{x}} E_{x0} \cos(\omega t - \beta z)$$

We know: $\omega = 2\pi f = \dfrac{2\pi}{T}$

Assume: $z = 0$

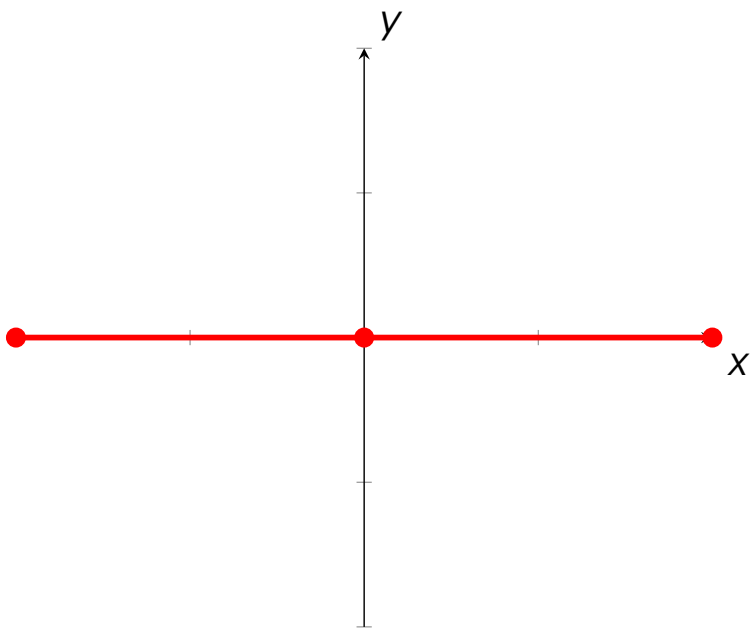
$$\vec{E}(0,0) = \hat{\mathbf{x}} E_{x0} \cos(0) = \hat{\mathbf{x}} E_{x0}$$

$$\vec{E}(0,\frac{T}{4}) = \hat{\mathbf{x}} E_{x0} \cos\left(\frac{2\pi}{T}\cdot\frac{T}{4}\right) = 0$$

$$\vec{E}(0,\frac{T}{2}) = \hat{\mathbf{x}} E_{x0} \cos\left(\frac{2\pi}{T}\cdot\frac{T}{2}\right) = -\hat{\mathbf{x}} E_{x0}$$

$$\vec{E}(0,\frac{3T}{4}) = \hat{\mathbf{x}} E_{x0} \cos\left(\frac{2\pi}{T}\cdot\frac{3T}{4}\right) = 0$$

$$\vec{E}(0,T) = \hat{\mathbf{x}} E_{x0} \cos\left(\frac{2\pi}{T}\cdot T\right) = \hat{\mathbf{x}} E_{x0}$$



Polarization $\Longrightarrow$ Linear

Uniform Plane Waves: Polarization # 2

$$\vec{E}(z,t) = \hat{\mathbf{x}} E_{x0} \cos\left(\omega t - \beta z + \frac{\pi}{4}\right) + \hat{\mathbf{y}} E_{y0} \cos\left(\omega t - \beta z + \frac{\pi}{4}\right)$$

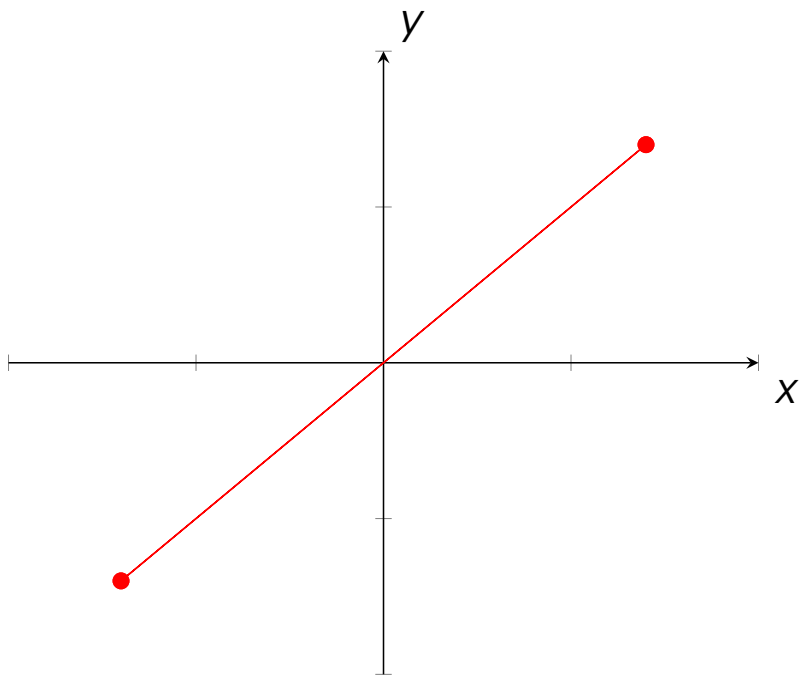
$$\vec{E}(0,0) = \hat{\mathbf{x}}\frac{\sqrt{2}}{2} + \hat{\mathbf{y}}\frac{\sqrt{2}}{2}$$

$$\vec{E}(0,\frac{T}{4}) = -\hat{\mathbf{x}}\frac{\sqrt{2}}{2} - \hat{\mathbf{y}}\frac{\sqrt{2}}{2}$$

$$\vec{E}(0,\frac{T}{2}) = -\hat{\mathbf{x}}\frac{\sqrt{2}}{2} - \hat{\mathbf{y}}\frac{\sqrt{2}}{2}$$

$$\vec{E}(0,\frac{3T}{4}) = \hat{\mathbf{x}}\frac{\sqrt{2}}{2} + \hat{\mathbf{y}}\frac{\sqrt{2}}{2}$$

$$\vec{E}(0,T) = \hat{\mathbf{x}}\frac{\sqrt{2}}{2} + \hat{\mathbf{y}}\frac{\sqrt{2}}{2}$$



Polarization $\Longrightarrow$ Linear, tilted 45°

Uniform Plane Waves: Polarization # 3

$$\vec{E}(z,t) = \hat{\mathbf{x}} E_{x0} \cos(\omega t - \beta z) + \hat{\mathbf{y}} E_{y0} \cos\left(\omega t - \beta z + \frac{\pi}{2}\right)$$

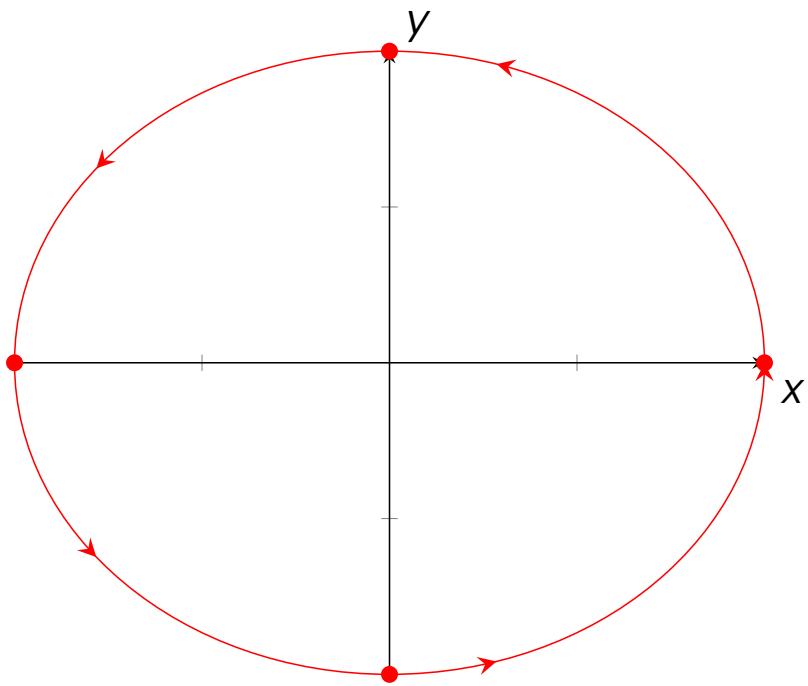
$$\vec{E}(0,0) = \hat{\mathbf{x}}$$

$$\vec{E}(0,\frac{T}{4}) = -\hat{\mathbf{y}}$$

$$\vec{E}(0,\frac{T}{2}) = -\hat{\mathbf{x}}$$

$$\vec{E}(0,\frac{3T}{4}) = \hat{\mathbf{y}}$$

$$\vec{E}(0,T) = \hat{\mathbf{x}}$$



Polarization $\Longrightarrow$ = RHCP

Uniform Plane Waves: Polarization # 4

$$\vec{E}(z,t) = \hat{\mathbf{x}} E_{x0} \cos\left(\omega t - \beta z - \frac{\pi}{2}\right) + \hat{\mathbf{y}} E_{y0} \cos\left(\omega t - \beta z + 0\right)$$

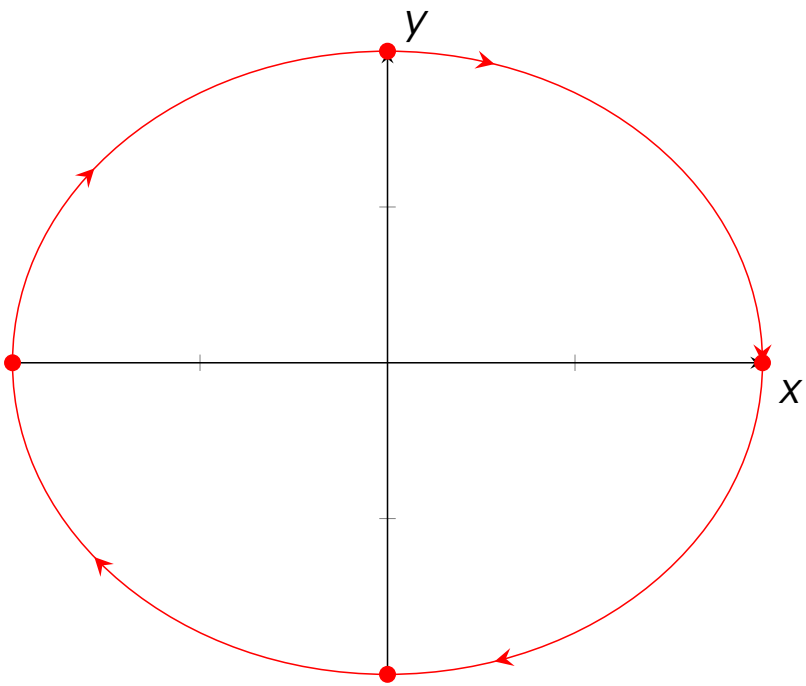
$$\vec{E}(0,0) = \hat{\mathbf{y}}$$

$$\vec{E}(0,\frac{T}{4}) = \hat{\mathbf{x}}$$

$$\vec{E}(0,\frac{T}{2}) = -\hat{\mathbf{y}}$$

$$\vec{E}(0,\frac{3T}{4}) = -\hat{\mathbf{x}}$$

$$\vec{E}(0,T) = \hat{\mathbf{y}}$$



Polarization $\Longrightarrow$ LHCP

Uniform Plane Waves: Polarization # 5

$$\vec{E}(z,t) = \hat{\mathbf{x}} E_{x0} \cos\left(\omega t - \beta z - \frac{\pi}{2}\right) + \hat{\mathbf{y}} E_{y0} \cos\left(\omega t - \beta z + \frac{\pi}{4}\right)$$

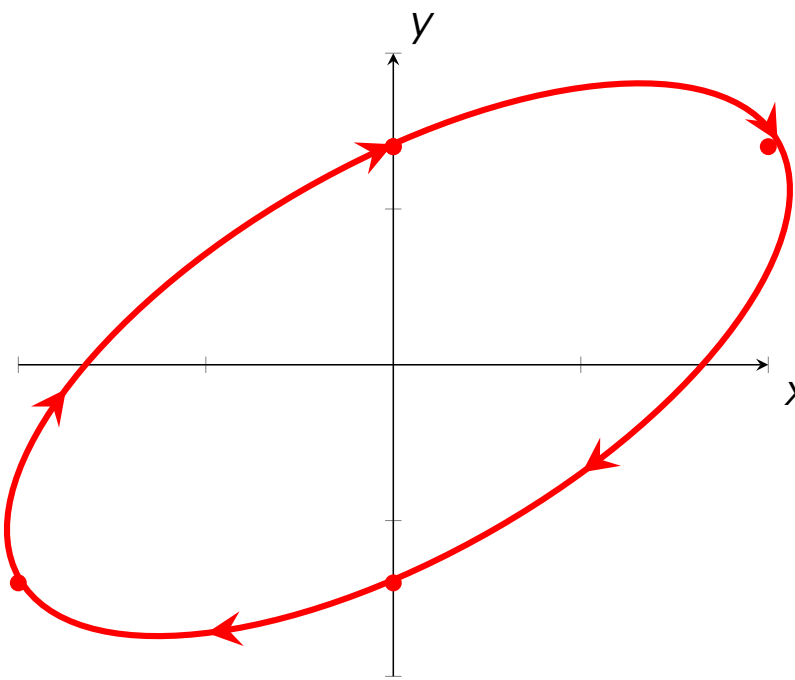
$$\vec{E}(0,0) = \hat{\mathbf{y}} \frac{\sqrt{2}}{2}$$

$$\vec{E}(0,\frac{T}{4}) = \hat{\mathbf{x}} + \hat{\mathbf{y}} \frac{\sqrt{2}}{2}$$

$$\vec{E}(0,\frac{T}{2}) = -\hat{\mathbf{y}} \frac{\sqrt{2}}{2}$$

$$\vec{E}(0,\frac{3T}{4}) = -\hat{\mathbf{x}} - \hat{\mathbf{y}} \frac{\sqrt{2}}{2}$$

$$\vec{E}(0,T) = \hat{\mathbf{y}} \frac{\sqrt{2}}{2}$$



Polarization $\Longrightarrow$ LHEP